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# The firm as Darwin Machine: an evolutionary view of organizational knowledge and learning

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## The firm as Darwin Machine: an evolutionary view of organizational knowledge and learning

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### Abstract

This paper argues that an evolutionary view of learning provides an explanatory logic for knowledge-based and capabilities-based theories of the firm. The paper develops a rigorous treatment of organizational learning as an evolutionary process on the basis of the notion of a generalized Darwinism and its application to knowledge. A Darwinian view of organizational learning demonstrates the logical imperative of distinguishing between organizational knowledge and organizational capabilities, and of understanding organizational learning in terms of the interplay between them. Work by Nelson and Winter, Penrose, and Burgelman is reinterpreted in Darwinian terms and implications for the nature of organizational capabilities and the locus of organizational knowledge are derived.

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# **The firm as Darwin Machine: an evolutionary view of organizational knowledge and learning**

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## 1. INTRODUCTION

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Knowledge-based, competence and capabilities-based, and dynamic capabilities views have become increasingly popular in both organizational economics and the managerial literature (cf. Dosi, Nelson and Winter 2000; Helfat 2003). What these theories share is a view of the firm as a repository of productive knowledge. But where does this knowledge come from? The answer, presumably, is that productive knowledge is the result of organizational learning. But how do organizations learn? And where does the resulting organizational knowledge reside?

Because of their respective theoretical aims, the different streams of theory development that have adopted a view of the firm as a repository of productive knowledge have given limited attention to learning as the basis of such knowledge. Evolutionary economics aims to explain population level phenomena (e.g. Nelson and Winter, 1982), the knowledge-based view aims to explain the existence of firms (e.g. Kogut and Zander, 1992; Foss, 1993, 1996; Grant, 1996; Spender, 1996), and the resource-based and dynamic capabilities views of the firm aim to explain performance differentials between them (e.g. Barney, 1991; Peteraf, 1993; Teece et al., 1997). Understanding productive knowledge as the result of an organizational learning process is secondary to these aims.

This paper explores organizational knowledge and learning from the perspective of evolutionary theory. Capturing the process of organizational learning and the nature of the knowledge that results from it is a major challenge for theory construction. Simple unidirectional causal explanations at a single level of analysis fall short of capturing the feedback loops and multi-level dynamics that are central to learning. Note that knowledge, the dependent variable of a theory of organizational learning, is a *state* of the organization, and that this state results from the *process* of learning. In other words, the explanation of knowledge does not rest on an independent variable (or a set of those variables), but rather on a process in time. This calls for another causal logic than the typical explanation of the type ‘X causes Y’.

The purpose of the paper is to demonstrate that the explanatory logic of Darwin’s theory of evolution offers a way to deal with the theoretical complications inherent in conceptualizing learning. As the paper will show, a generalized version of Darwinism is especially well suited to capture the multi-level dynamics and feedback loops that are central to learning. It will be argued that firms can be usefully modeled as ‘Darwin machines’ that develop productive knowledge as the result of learning processes that can be understood in terms of the Darwinian variation-selection-retention algorithm.

Darwinism can thus be seen as a way to ground knowledge-based and capabilities-based theories in an explanatory logic that is uniquely capable of addressing the dynamics of organizational learning.

The crucial insight that can be derived from the application of the Darwinian logic to organizational learning is the logical imperative to disentangle organizational knowledge and organizational capabilities. The causal structure of Darwinism captures the relationship between organizational knowledge and organizational capabilities, and demonstrates that organizational learning can only be fully understood in terms of the interplay between them.

The paper develops a generalized evolutionary explanation of learning that is subsequently used to reinterpret Nelson and Winter (1982), Penrose (1959) and Burgelman (1991) in terms of the Darwinian logic. We show that the seminal work of Nelson and Winter fails to make the necessary distinction between knowledge and capabilities, and contrast it with the work of Penrose and Burgelman. While the work of none of these authors meets all of the necessary criteria for a Darwinian theory of organizational learning, each of them provides essential building blocks for a theory that can meet the logical criteria of a Darwinian explanation. The paper discusses these building blocks and how they can be combined, and derives implications for the nature and locus of a firm's productive knowledge.

## 2. LEARNING AS AN EVOLUTIONARY PROCESS

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The first section of the paper develops a Darwinian view of learning. The argument that organizational learning can be understood as an evolutionary process is based on the notion of ‘generalized Darwinism’ and its application to knowledge. We first explain the idea of generalized Darwinism. We then turn to its application to knowledge and explain the concept of a ‘Darwin machine’. The section concludes with a general framework that captures the Darwinian view of learning and demonstrates the crucial distinction between knowledge and behavior.

### 2.1. Generalized Darwinism

Generalized Darwinism is the idea that the explanatory structure that is central to Darwin’s theory of evolution applies to the evolution of all open, complex systems (Campbell, 1960, 1965; Lewontin, 1970; Cziko, 1995; Dennett, 1995; Hull et al. 2001; Hodgson, 2002; Knudsen, 2002; Stoelhorst, 2005a; Hodgson and Knudsen, forthcoming). A complex system can be defined as a system that is composed of a number of interacting elements (cf. Simon 1981). An open system can be defined as a system that requires resources from its environment to function. Firms are open, complex systems, and if we accept the claim of generalized Darwinism, it follows that their evolution can be explained in Darwinian terms.

So what, exactly, is the nature of Darwin’s theory? In its most general form, a Darwinian theory of evolution involves mechanisms to introduce variations, a consistent selection process, and mechanisms for preserving and/or propagating the selected variants (Campbell, 1960, 1965; Plotkin, 1994). The claim of generalized Darwinism is that the explanatory structure of the triumvirate of ‘variation’, ‘selection’ and ‘retention’ holds across domains. In itself, the Darwinian logic is substrate neutral, and the specific mechanisms of variation, selection and retention can be expected to differ between systems. In general, a Darwinian theory can therefore be understood as a specification of how variation, selection and retention work for the system in question.

The idea that Darwin’s theory may be applied outside biological evolution has a long history.<sup>1</sup> In strategy and organization studies, it has been taken up and applied to firms by scholars from a variety of disciplinary backgrounds (e.g. Hannan and Freeman, 1977; Aldrich, 1979, 1999; Weick, 1979;

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<sup>1</sup> It starts with Darwin himself, who applied it to the evolution of language, includes Social Darwinism, the movement that has brought it into disrepute, and more recently, Sociobiology, Evolutionary Psychology, and Memetics. For a balanced review of these different strands of evolutionary theorizing see Laland and Brown (2002).

Nelson and Winter, 1982; Burgelman, 1991; Baum and Singh, 1994; Barnett and Burgelman, 1996). Most of these applications either use Darwinism as a metaphor for the competition between firms, or take inspiration from analogies to biological evolution to elucidate how firms change over time. But generalized Darwinism is *not* based on biological metaphors or analogies, but on the claim that on a sufficiently general level of abstraction all evolutionary processes are ontologically similar (cf. Hodgson, 2002; Hodgson and Knudsen, forthcoming). In the words of Plotkin: ‘*The actual mechanisms in each case, of course – and one cannot repeat this point often enough – are entirely different*’ (1994, p.100, emphasis in original). But the explanatory structure provided by Darwin is universal and holds *regardless* of the nature of variation or the mechanisms for retaining favorable variations.

This claim extends to situations where human intentionality is involved. The classic objection to the application of Darwinism in the social sciences is that intelligent agents would change the evolutionary dynamic that Darwin set out to explain. In nature, variation is random, which is to say that it is blind to the selection pressures that the organism faces. This feature of biological evolution has long been a reason to call economic evolution Lamarckian (Penrose 1952; Nelson and Winter, 1982). Humans can be expected to vary their behavior in a way that *does* reflect the selection pressures they face, so that cultural evolution can be expected to involve directed, rather than blind, variation. Moreover, cultural evolution allows the inheritance of acquired characteristics, or in other words, of adaptations that were not encoded in genes but emerged during an organism’s lifetime, something that is impossible in nature. But there is nothing about generalized Darwinism to stipulate that all evolutionary processes should involve blind variation, nor that they cannot involve the inheritance of acquired characteristics (Knudsen 2001; Hodgson 2001). All that is needed is a mechanism for the replenishment of variety, whatever the form, and a mechanism to selectively retain the variations that work.

As Dennett (1995) has pointed out, a Darwinian explanation is in essence an algorithmic explanation: if there is a consistent selection process, and if there are mechanisms for introducing variations and retaining the favorable ones, evolution *will* occur. What has received much less attention in the applications of Darwinism in economics and organization theory is what the phrase ‘evolution will occur’ means. Its most basic interpretation is simply that the system in question changes over time, and this is the way in which the term is typically used by economists and management scholars. But Darwin’s theory does more than explain how change can come about. It explains *adaptive fit*, or why systems are so remarkably well adapted to the environments in which they function (Stoelhorst,



2005b). It is this feature of Darwin's theory that makes it relevant to understanding organizational learning.

## **2.2. Learning as a Darwinian Process**

Barring on omniscient designer, the variation-selection-retention logic of generalized Darwinism is the only logically consistent and complete explanation to account for adaptive fit. Adaptive fit is the state that allows an open, complex system to extract the resources necessary for survival from its environment, and may involve any number of adaptations to that environment. Adaptations are simply features of the system that allow it to function successfully. They come about through the interplay of mechanisms to introduce variation in the ways a system interacts with its environment, a consistent selection process, and mechanisms to retain those variations that work. The effect of the interaction of the three Darwinian mechanisms will be that the system in question is a quite literal sense informed by its environment (Plotkin, 1994).

Adaptations can thus be understood as beneficial features of a system shaped by interaction with the environment. Two features of adaptations are important. The first is their goal-directed nature. Every adaptation is 'for' something. The second is their relational quality. Every adaptation is some form of organization of the system relative to some feature of environmental order. Adaptations simply cannot be seen in isolation from the environmental factors that have provided the selection pressures for them. The goal-directed property of adaptations can only result if adaptations are 'in-formed' by features of the world; 'they are highly directed kinds of organization, and not random, transient structures that may or may not work. Adaptations do work, and they work precisely because of this 'in-forming' relationship between organismic organization and some aspect of the order of the world' (Plotkin 1994, p.118).

Plotkin (1994) convincingly argues that given these two characteristics adaptations and knowledge are essentially the same thing. '[A]ll adaptations are instances of knowledge, and human knowledge [as commonly understood] is a special kind of adaptation' (p.117). His argument builds on a longer tradition in the branch of philosophy known as evolutionary epistemology (Campbell 1974; Popper 1972) and proceeds in three steps: (1) knowledge as commonly understood is a way of 'incorporating' aspects of the world; (2) the human capacity to gain knowledge is a biological adaptation that needs an evolutionary explanation; (3) adaptations are themselves ways of incorporating the world into the structure and organization of living things. The conclusion is that 'adaptations are biological knowledge, and knowledge as we commonly understand the word is a special case of biological knowledge' (p.xv).

The insight that adaptations are a form of knowledge, and knowledge as commonly understood a form of adaptation, is central to the argument that learning is an evolutionary process. If learning is the process that leads to knowledge and evolution the process that leads to adaptations, then equating knowledge and adaptations means that learning is an evolutionary process. In keeping with the tenets of evolutionary epistemology and generalized Darwinism, it follows that the Darwinian logic can explain the process of learning.

Plotkin (1994) uses the concept of a 'Darwin machine' to underscore the point that learning is an evolutionary process.<sup>2</sup> A Darwin machine is any system whose transformation over time through successive adaptive states is explained by a process of variation, selection and retention. Populations of entities without any capacity for individual learning can function as a Darwin machine, as long as selective pressure from the environment affects the differential propagation of these entities over time. This is how natural selection in biology works on populations. Variations in the genotype of the population lead to differences in the phenotypes that constitute the population, and the genetic information of the phenotypes that do not reproduce is lost, while the genetic information of those phenotypes that do successfully reproduce is retained. In other words, natural selection causes differential reproduction and thus provides the necessary feedback loop to make the Darwinian algorithm work.

There are, in fact, a number of other systems that can be understood as Darwin machines and that have been described as such. These include the immune system, the brain, and the scientific enterprise (Plotkin 1994; Cziko 1995; Dennett 1995; Hull et al. 2001). The tenets of generalized Darwinism suggest that if different types of individual learning can be understood as a Darwinian process, we may follow a similar route when modeling organizational learning. After all, organizations, like organisms, are open complex systems that depend on scarce resources from the environment to survive. Modeling organizational learning as a Darwinian process that leads to behavioral adaptations would ground theories of organizational learning in a proven logic that was specifically developed for a multi-level process involving feedback loops. But before we undertake this task, we need to further clarify the nature of this logic.

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<sup>2</sup> Plotkin credits William H. Calvin for coining the term 'Darwin machine'.

### **2.3. The Explanatory Structure of Darwinism**

The notion of adaptation (note that we are here referring to the noun, not the verb), is closely linked to functional explanation, which has had its share of criticism because it can easily lead to evolutionary ‘just-so’ stories that reek of Panglossian pan-adaptationism where ‘everything is for the best in the best of all possible worlds’. A normal scientific explanation would explain a phenomenon in terms of its cause, whereas a functional explanation explains the features of a system (say, the wings of a bird) in terms of its function (flight). Vromen (1995, p.90-91) discusses the classic objection to functional explanations of the existence of a feature, which hinges on the recognition that functions are not causes but effects. A functional explanation therefore seems to reverse the logic of cause and effect: flight does not cause wings, it is having wings that makes flight possible. The problem is that wings are a sufficient, but not necessary condition for flight: there may well be functional equivalents that could have provided the same function.

Let us now try to further unravel this logic. We are dealing here with a functional explanation that accounts for the state of a system in relation to its environment in terms of the algorithmic process that has led to this state. There are three necessary conditions for a functional explanation. A behavioral pattern X is explained by its function Y for system Z if and only if:<sup>3</sup>

Y is an effect of X;

Y is beneficial for Z;

Y maintains X by a causal feedback loop passing through Z.

The third condition needs further clarification and brings us to the distinction between genotype and phenotype. In biology the phenotype is the combination of the organism’s morphology and behavioral repertoire that determines the way in which it interacts with its environment. The organism’s phenotype is derived from the genotype, the genetic information that codes for the way in which the phenotype develops. The genotype both enables and constrains the organism’s interaction with its environment. The distinction between genotype and phenotype is essential to the way in which the

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<sup>3</sup> These conditions are derived from Elster (1979, p.28), who derives five conditions for a functional explanation in the social sciences. His formulation is as follows. An institution or behavioral pattern X is explained by its function Y for group Z if and only if: (1) Y is an effect of X; (2) Y is beneficial for Z; (3) Y is unintended by the actors producing X; (4) Y (or at least the causal relationship between X and Y) is unrecognized by the actors in Z; (5) Y maintains X by a causal feedback loop passing through Z. However, given the premise of generalized Darwinism, conditions 3 and 4 are superfluous. The Darwinian algorithm also works when intentionality is involved (Dennett 1995; Hodgson 2001; Knudsen 2001; Stoelhorst 2005b).

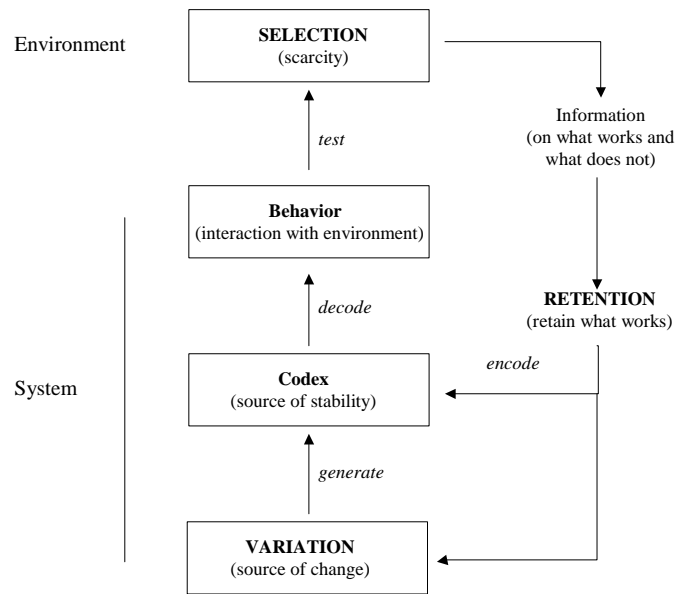
Darwinian algorithm works. Over time, there needs to be a causal feedback loop from the phenotype to the genotype. In biology, this causal feedback loop is provided by differences in reproductive success. The fact that some organisms are more successful in propagating their genes will change the composition of the genotype from one generation to the next.

The distinction between genotype and phenotype is a fundamental part of a Darwinian explanation. For the Darwinian algorithm to work, there must be way to retain information about what has worked in the past, and this information must underwrite the way in which a system interacts with its environment. It follows that we need to understand open, complex systems in terms of the way they interact with their environment, or their *behavior*, and in terms of what ‘codes’ for that behavior, or their *codex*.<sup>4</sup> This codex can be understood as the accumulated information about what has worked in the past. The notion of ‘Y maintains X by a causal feedback loop passing through Z’ can thus be generalized to: the relative success of different behaviors in the interaction with the environment changes the codex of the system so that the likelihood that the system displays successful behaviors increases.

We now have all the necessary building blocks to generalize the Darwinian logic. These building blocks are (1) the Darwinian algorithm consisting of the interplay between variation-selection-retention mechanisms; (2) the genotype/codex – phenotype/behavior distinction; (3) the three necessary conditions for a functional explanation, central to which is the feedback loop. Figure 1 shows how these building blocks combine to explain how open, complex systems become adapted to their environment.

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<sup>4</sup> We adopt this term from Wilkins (2001).



**Figure 1: A generalized Darwinian framework**

The logic of the figure is as follows. Open, complex systems consist of different components and need resources from their environment to function. To secure the necessary resources an open system needs to interact with its environment. This interaction is what we call behavior, the act of doing something to have an effect upon the outside world (cf. Plotkin 1994, p.104). The system is subjected to selection pressure to the extent that the resources it requires to survive are scarce. Information on the ways of interacting with the environment that work and don't work is fed back into the system and accumulated in its codex (the top part of the feedback loop from environment to system). Decoding this accumulated information in reaction to internal or external cues makes it more likely that behaviors that were successful in the past are repeated in future interactions with the environment. The codex of a system is a necessary source of stability in the evolutionary process. Complex systems consist of interacting components and necessarily involve information that specifies the components of the system and a design that specifies the way they interact. Random changes in these specifications are more likely to negatively affect the functional integrity of the system than to improve its performance. Yet in the long run, there needs to be a way for the system to vary its behavior if it is to be able to adapt to changing environmental conditions. Such variation can only result from changes in the system's codex, either by changing the components that make up the system, or by changing the way they interact. These changes can either be blind, or informed by the nature of the selection

pressures faced by the system (in which case the bottom part of the feedback loop from the environment to the system comes into play).

### **3. THE FIRM AS A DARWIN MACHINE**

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We have so far argued (1) that knowledge and adaptive fit are one and the same concept, (2) that generalized Darwinism offers a rigorous theory to explain adaptive fit, and, by extension, knowledge, and (3) that learning can therefore be understood as a Darwinian process. Darwin machines learn as a result of the interplay of variation, selection and retention mechanisms. This interplay establishes a feedback loop by which information about the success of behavioral interactions with the environment is encoded in the system so that cues that trigger future interactions are more likely to result in functional behavior.

Two questions were posed in the introduction of this paper: how do organizations learn and where does the resulting organizational knowledge reside? On the basis of the discussion in the first part of the paper, we can now answer these questions, albeit in very general terms. Organizations learn as the result of the interaction of variation, selection and retention mechanisms, and organizational knowledge resides in the codex of the organization. To consider the firm as a Darwin machine, the task we face is to detail the nature of the mechanisms of variation, selection and retention that shape the firm's evolution, as well as the nature of the codex that provides for stability in the firm's interaction with the environment over time.

This is not unlike the task that Nelson and Winter set themselves in '*An Evolutionary Theory of Economic Growth*', and this will therefore serve as the natural starting point of an attempt to consider the firm as a Darwin machine. However, as will become clear below, when considered in light of the Darwinian framework discussed above, there are a number of ambiguities in Nelson and Winter's treatment of organizational change. Additional insights in organizational learning and the codex of the firm can be derived from a number of other sources whose perspective on organizational change is different from that of Nelson and Winter, yet compatible with the notion of the firm as a Darwin machine. We will consider the work of Penrose (1959) on the growth of the firm, and Burgelman (1991) on internal corporate venturing. For each of the theories discussed we ask the following questions: What does the theory suggest about the mechanisms of variation, selection and retention that drive organizational change and adaptation? And what does the theory suggest about the nature of the codex of the firm, or in other words, the elements that make up the firm and the way in which

these elements interact to enable functional behavior? Tables 1 and 2 summarize the discussion that follows.

	<b>Variation</b>	<b>Selection</b>	<b>Retention</b>
Nelson & Winter	Routinized Search	Competition in the market	Exercising routines
Penrose	Productive services of resources	Image of productive opportunities	Resources
Burgelman	Strategic initiatives	Internal and external selection environment	Official strategy

**Table 1: The Darwinian algorithm**

	<b>Elements of the codex</b>	<b>Interaction of the elements to produce functional behavior</b>	<b>Feedback loop</b>
Nelson & Winter	Routines	?	Profitability of activities
Penrose	Resources	Administrative framework	?
Burgelman	Strategic initiatives	?	Strategy process

**Table 2: The Darwinian causal logic**

### **3.1. Nelson and Winter: Genes, routines, and organizational memory**

When discussing the way in which Nelson and Winter's work helps us understand the process of organizational learning we should first of all note that it was not developed for this particular purpose. Nelson and Winter set out to develop a theory of economic change that is first and foremost concerned with explaining phenomena at the level of industries. Yet, one of their important achievements was that they grounded their theory in a rich discussion of the inner workings of the firm, and another that

they framed this discussion in explicitly Darwinian terms.<sup>5</sup> We may therefore also expect their work to shed some light on the questions that concern us here.

Given their explicit use of Darwinian terminology, let us first consider what Nelson and Winter say about the mechanisms of variation, selection and retention that shape organizational change. The central concept in Nelson and Winter's work is that of an organizational routine. Routine is their 'general term for all regular and predictable behavioral patterns of firms' (p. 14), and it is this regular, predictable and recurrent behavior that is the centerpiece of an evolutionary logic in which 'routines play the role that genes play in biological evolution' (p.14). In other words, routines provide the necessary stability in behavior over time that is required for the Darwinian algorithm to work. More specifically, it is by exercising routines that an organization retains its productive knowledge. In addition, of course, there needs to be a consistent selection pressure and a source of variation. The first is provided by the scarcity of resources for which firms compete in the market, and the second by higher level 'search' routines by which firms look for ways to modify their lower level 'operating' routines.

How does this view of the firm map unto the Darwinian logic discussed above? Unfortunately, this is not at all clear. As has been pointed out elsewhere, there are some ambiguities in Nelson and Winter's treatment of routines (Hodgson 2002; Becker 2005). If routines were the analogue to genes, we would expect them to be what codes for functional behavior and not to be defined in terms of the behavior itself, as Nelson and Winter do. The notion of 'routines as genes' would mean that we are talking about the firm's codex, yet the definition of routines as recurrent patterns of behavior immediately shifts our focus to what is actually selected by the market. In other words, *the notion of organizational routines conflates the codex and behavior of the firm*. What we are left with is a view of the firm as a set of recurrent action patterns that are subject to selection by the market. What the source of variation in these patterns is, or how they are retained through time, is not clear.

Whereas it is easy to distill the three Darwinian mechanisms from Nelson and Winter's work, it is not immediately clear how we can derive insights about the codex of the firm from their work. To better understand the nature of the codex we need to specify both the sources of variety and the sources of stability in the behavior of firms. Merely using the notion of routine as shorthand for the claim that there is such stability over time will not do. Rather, we have to unearth the actual mechanisms that give rise to recurrent action patterns (Becker, 2005). Nor does invoking higher-level routines as a

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<sup>5</sup> This is despite calling their theory Lamarckian. For a convincing discussion of why Nelson and Winter's work can be appropriately viewed as Darwinian see Hodgson (2002).



source of change in lower level routines help much in understanding the source of variety in the behavior of firms. This is a way of hiding individual behavior and initiative in the folds of an infinite regress of ever-higher levels of routines. This way of treating the sources of variety is ironic for a theory that professes to be ‘unabashedly Lamarckian’ (p.11), because it does away with the need to incorporate intentional behavior in an explanation of how firms learn. In fact, as the nature of their formal models shows, the resulting explanatory logic works equally well with an entirely stochastic generation of variety. By modeling the codex of the firm in terms of a hierarchy of routines and by thus putting all the explanatory power of the theory in the collective phenomenon of routines, the role of individual behavior in shaping the actual behavior of firms is lost.

The fact that Nelson and Winter conflate codex and behavior and view the codex of the firm in terms of a hierarchy of routines is best understood in light of their goal to construct quantitative models of industry-level phenomena. There is a notable difference between these modeling efforts and the so-called ‘appreciative theorizing’ in the first chapters of their book. The problematic notion of routines in fact hides a much more subtle discussion of the internal workings of the firm that can give us some more detailed pointers to the mechanisms that may account for the simultaneous stability and change in the behavior of firms. In their discussion of ‘routine as organizational memory’ they discuss individual members of the organization as the locus of much of the information that is required for the performance of organizational routines, but emphasize that organizational memory is not reducible to the memories of individuals. This would ‘overlook, or undervalue, the linking of those individual memories by shared experiences in the past, experiences that have established the extremely detailed and specific communication system that underlies routine performance’ (p. 105).

This seems to establish two points. First, individual behavior does matter in understanding the routines of firms. Second, individual behavior can become part of a recurrent pattern of coordinated behavior by responding to an ‘extremely detailed and specific communication system’. It would seem that it is this communication system that we need to unravel to really understand the nature of the codex that provides the stability in coordinated behavior. This idea is reinforced by Nelson and Winter’s remark that to establish a new routine where none exist before, ‘organization members have to learn the system of coordinating messages. They may have to add new skills to their individual repertoires, and they need to achieve a first reconciliation of their expectations regarding the distribution of costs and benefits in the new situation’ (p.112).

The comment about a reconciliation of expectations relates to their discussion of ‘routine as truce’. Again we see an explicit consideration of how individual behavior becomes part of a coordinated

action pattern. Whereas the ‘routine as organizational memory’ considers the cognitive aspect of how individuals behave (do they know what to do, and how to do it), the ‘routine as truce’ considers the motivational aspect (do they actually choose to do what is required of them in the routine operation of the organization as a whole). Nelson and Winter emphasize that ‘routine operation should not be confused with performance according to the nominal standards of the organization’ (p.108). ‘The usual mechanisms of internal control are, of course, a part of the context that helps define the *de facto* contracts that individual members make with the organization’ (p.108-9). But ‘[w]hat signals the existence of an accommodation is not the conformity of behavior to standards of performance laid down by supervisors or codified in job descriptions, but that members are rarely surprised at each other’s behavior ...’ (p.108). ‘In routine operation, the combined effect of the rule-enforcement mechanism and other motivators is such as to leave the members content to play their roles in the organizational routine – but content only in the sense that they are willing to continue to perform up to their usual standard ...In short, routine operation involves a comprehensive truce in intra-organizational conflict’ (p.110).

We may conclude that Nelson and Winter’s idea of routines as the building blocks of organizational capabilities is problematic, because both routines and capabilities are defined in terms of behavior, and not in terms of the knowledge that underlies and enables that behavior. The idea of a hierarchy of routines, while useful as a modeling tool, does not help us to unravel where organizational knowledge is stored so that functional behavior can be reliably repeated over time. The notion of routines as the genes of organizations as such does not tell us anything about how individual behaviors can become part of coordinated behavior patterns. However, the discussions of ‘routine as organizational memory’ and ‘routine as truce’ begin to convey a picture of individuals adapting to a complex intraorganizational environment consisting of a ‘system of coordinating messages’ (p.112), an ‘organizational dialect’ (p.104), and ‘a peculiar symbolic culture’ (p.111). Moreover, routines can also take on the quality of norm or target, and be ‘imposed on a continually changing set of resources’ (p.113). Such ideas can be found in more developed form in the work of Penrose and Burgelman.

### **3.2 Penrose: Resources, productive services and the administrative framework**

There is an obvious irony in discussing the work of Penrose (1959) in Darwinian terms, because she wrote a widely quoted critique of the invocation of biological analogies in economics (Penrose, 1952). But our discussion of generalized Darwinism has given us two reasons to proceed along these lines. First, Penrose’s main objection to the use of evolutionary analogies, that intentional behavior cannot be readily accommodated in an evolutionary framework, can now be seen as misconstrued. Second, the generalized notion of a Darwin machine makes developmental processes amenable to an

evolutionary analysis. Since *'The Theory of the Growth of the Firm'* is arguably the seminal statement of organizational change in developmental terms, this makes it interesting to see how it maps unto the Darwinian logic.

Although Penrose repeats her criticism of biological analogies in the introductory chapter of her book, she does use evolutionary terminology metaphorically. The term growth is used to denote 'an increase in size or an improvement in quality as a result of a process of development, akin to natural biological processes in which an interacting series of internal changes leads to increases in size accompanied by changes in the characteristics of the growing object' (p. 1). And 'growth is essentially an evolutionary process and based on the cumulative growth of knowledge, in the context of a purposive firm' (p. xiii). It is this qualitative change that is her interest, and the size of the firm is seen as 'but a by-product of the process of growth' (p.2). Her theory explains the direction of expansion of the firm as driven by its 'inherited resources' (p.5) and its perception of productive opportunities, and the rate of expansion as limited by its capacity of experienced managerial resources.

As we may expect given her criticism of biological analogy, Penrose does not explicitly develop her theory of the growth of the firm in terms of variation, selection and retention. She is, however, quite explicit about the elements of the firm that are central to her analysis of how firms change: firms are seen as a collection of resources governed by an administrative framework. With this definition, her view of the codex of the firm is immediately clear: the specific resources in the firm's possession and the way in which they are administered provide stability to the firm's activities. However, the resources are also the source of variety in the firm's activities over time. This is because each resource can provide a variety of productive services. Whenever there is excess capacity of resources and the firm perceives a productive opportunity, it will expand its activities. The resources of the firm thus both enable and constrain its growth.

Resources come in two forms: they include the employees of the organization as well as any other productive resources. Managerial resources are central to the argument: there needs to be an excess capacity of experienced managerial resources for firms to pursue new productive opportunities. The specific productive opportunities that are in fact pursued depend on the way managers perceive the competitive environment. 'The environment is treated, in the first instance, as an 'image' in the entrepreneur's mind of the possibilities and restrictions with which he is confronted' (p.5). This results in a rather voluntaristic argument. '[T]he environment is not something 'out there, fixed and immutable, but can itself be manipulated by the firm to serve its own purposes' (p.xiii). It is therefore not demand that limits the growth of firms, but the internal developmental process: 'a firm's rate of

growth is limited by the growth of knowledge within it, but a firm's size by the extent to which administrative effectiveness can continue to reach its expanding boundaries' (p. xvii).

Penrose's theory offers us a view of organizational change that differs from that of Nelson and Winter in a number of ways. First, whereas Nelson and Winter take their starting point in routines, or what firms *do*, the point of departure in Penrose's analysis is resources, or what firms *have*. Second, whereas Nelson and Winter subsume individual behavior in their notion of collective routines, Penrose explicitly sees managerial experience and perception as the drivers of organizational change. Third, whereas Nelson and Winter's firms are single product firms, Penrose's firms are explicitly multi-product. Fourth, while Nelson and Winter are very much concerned with how external market pressures mold the firm, Penrose is primarily concerned with how managers determine the size and shape of the firm from within. These differences lead to a view of organizational change that nicely complements that of Nelson and Winter by focusing on the resources underlying the activities of the firm and by giving more explicit attention to the role of individual perception and action in shaping organizational change.

Restated in Darwinian terms, the firm's resources serve as the source of stability in its activities, their differing productive services as a source of variety, and managerial perceptions of the environment as the source of selection. However, what the Penrosian theoretical structure is missing to qualify as a fully developed Darwinian account of learning is the feedback loop by which information on what works and what doesn't work is fed back into the firm. This is already clear in the introductory chapter, where she addresses the 'alleged tautological problem which some have feared is inherent in a theory of the growth of firms concerned only with firms that can successfully grow' (p.7). What follows is a rather unconvincing argument in which she states that here concern is merely to answer the question: 'assuming that some firms can grow, what principles will then govern their growth, and how fast and how long can they grow?' (p.7). The rest of the book, of course, develops an admirable answer to this question. But the argument would have certainly gained in strength if it had also incorporated the population level logic of Nelson and Winter and included a more explicit analysis of the effects of competition between firms on their relative success. In the Penrosian view, the experienced manager almost takes the form of an omniscient designer. It is his 'image' of the productive opportunities in the environment that matters 'for it is, after all, such an 'image' which in fact determines a man's behavior; whether experience confirms expectations is another story.' (p.5). However, a Darwinian account means also telling that other story.

### **3.3 Burgelman: Strategic initiatives and the internal selection environment**

Burgelman has explicitly used Darwinian terminology to address how organizations change as the result of intrapreneurial activity (Burgelman 1983, 1991; Barnett and Burgelman, 1996). Because his analyses are explicitly framed in terms of variation, selection and retention mechanisms, it is relatively easy to map his work unto the Darwinian logic. The source of variation in firms comes from strategic initiatives taken by the firm's employees. These initiatives are selected in the internal selection environment of the firm, and those that are successful are retained in the firm's official strategy.

Burgelman distinguishes two types of initiatives that may play a role in shaping the activities of firms: there are initiatives that are induced by the official strategy of the firm, and there are so-called autonomous initiatives that fall outside the official strategy. The organization is seen as 'an ecology of strategic initiatives which emerge in patterned ways, and compete for limited resources so as to increase their relative importance' (1991, p. 240). 'Structural and strategic contexts, together, constitute selection processes operating on strategic initiatives' (1991, p. 250). Strategic initiatives that succeed in attracting limited resources like managerial attention and investment funds shape organizational change. Successful initiatives are retained by incorporation in the official strategy of the organization that articulates the character, goals and domains of the organization.

This view has a number of implications for our understanding of the nature of variation, selection and retention, as well as the nature of the codex of a firm. Most importantly, in addition to being subject to selection pressures from the market, the firm can itself be seen as a selection environment in which individuals compete for career advancement on the basis of strategic initiatives. Selection can thus be seen to simultaneously operate on two levels: within the firm, and on the firm as a whole. The central question is 'how internal selection may combine with external selection to explain organizational change and survival' (1991, p. 239). 'The effectiveness of internal selection processes may depend on how closely they correspond to the selection pressures exerted by the current external environment, while simultaneously allowing new environments to be sought out' (1991, p. 250).

Like Penrose, Burgelman is primarily concerned with detailing how processes internal to the firm cause organizational change. However, in light of the Darwinian framework, there are three important contributions in Burgelman's work. First, there is the recognition that in addition to the available resources, the details and outcome of the strategy process are important determinants of the specific activities undertaken by firms. Second, the account of the inner workings of the firm is explicitly framed in selectionist terms. Whereas Penrose seems to sidestep the inherent conflicts of interest that accompany the choice between the different productive services that resources can render, these are

central to the view of the firm as an internal selection environment. Third, Burgelman explicitly considers how internal selection may combine with external selection to explain organizational change and survival. Like Penrose, Burgelman's view of the firm is somewhat voluntaristic. Firms can seek out new environments, and adapt their strategies to changing market pressures. However, such successful reorientations are likely to have been preceded by internal experimentation and selection processes. Organizations that create enough slack in their strategy process to allow for autonomous initiatives and hence stimulate variety are more likely to successfully adapt to changing selection pressures from the market.

The main strength of Burgelman's perspective is that it is explicitly multi-level and thus establishes a link between Nelson and Winter's concern with selection by the market with Penrose's concern for internal developmental processes. The necessary feedback loop is provided by the strategy processes in which the relative success of the firm's activities is fed back into the firm's strategy 'based, at least in part, on retrospective sense making and attempts to capture top management's learning about the basis for the organization's success' (1991, p. 243). The main weakness of Burgelman's perspective is that its focus on strategy and strategic initiatives puts the explanatory burden exclusively on cognition and decision-making, or on what firms *want* to do, and abstracts from the activities that are actually performed. This is most obvious in his view of the firm as an ecology of strategic initiatives. What is missing from this view is a detailed analysis of the actual capabilities on the basis of which firms compete and of the productive knowledge that underlies them.

#### **4. DISCUSSION**

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The first part of the paper used generalized Darwinism to better understand the nature of knowledge and learning. A rigorous treatment of learning as an evolutionary process shows that we need to logically distinguish knowledge from behavior. Knowledge is what enables functional behavior. For such knowledge to develop, there needs to be a source of variation in behavior, and there needs to be a feedback loop to what codes for that behavior. This feedback loop needs to have the effect that it increases the likelihood that behaviors that worked in the past are repeated in future interactions with the environment. Barring an omniscient designer, the Darwinian variation- selection-retention algorithm is both a necessary and sufficient condition for learning to occur.

Knowledge-based and capabilities-based theories of the firm have typically not been much concerned with the causal logic of the learning process from which the firm's productive knowledge results. If we want to do more than merely postulate the existence of productive knowledge, we need to

understand this knowledge as the result of an evolutionary process. The Darwinian framework suggests that to understand organizational learning as the source of productive knowledge, there is a logical imperative to disentangle organizational capabilities from the knowledge underlying them. Organizational capabilities are functional behaviors, and organizational knowledge is what enables those behaviors. This knowledge results from an evolutionary process, in which information about the functionality of different behaviors is fed back into the system in such a way that behaviors that work are retained. The essential task in understanding organizational learning, then, is to understand how organizations are able to achieve this selective retention of functional behavior. Where in the organization does the information about what works reside? The general term for where knowledge resides in the Darwinian framework developed in the first half of the paper is the ‘codex’ of a system. The codex can be understood as the specification of the elements of the system and the way in which they interact to produce functional behavior. The codex is what both enables and constrains the behaviors of the firm.

The second part of the paper has considered three theories that offer important insights into the nature of the codex of a firm. Penrose provides a baseline specification of the constituents of the firm and the way they interact. Firms are a collection of resources and these resources are ‘bound together’ in an administrative framework. Resources come in two forms: they include the individual members of the organization and the (im)material assets that are at the firm’s disposal. These resources both enable and constrain the behavior that the firm is capable of. The administrative framework governs how they interact to produce that behavior.

What is not immediately clear from the Penrosian framework is how firms are able to adapt to their environments and develop functional behaviors. To qualify as a theory of organizational learning, the theory of the growth of the firm lacks an explicit feedback loop. This feedback loop is central to the work of Nelson and Winter with its emphasis on selection by the market. In their formal models, the relative profitability of the activities of the firm determines the expansion or contraction of these activities. However, by simply postulating the existence of operational routines and search heuristics to modify these routines, Nelson and Winter’s models sidestep how this expansion or contraction is achieved.

To better understand how information about what works becomes encoded in the firm, we need to look beyond the mere notion of routinized behaviors as the building blocks of organizational capabilities. This is in the spirit of Nelson and Winter’s appreciative theorizing, which offers some insights in the mechanisms that allow firms to retain behaviors that work. However, to qualify as a



theory of organizational learning, their evolutionary theory of economic change lacks the multi-layered structure needed to distinguish behaviors from the knowledge that enables them. This is most obvious in the way in which they subsume individual behaviors in the notion of organizational routines.

Both Penrose and Burgelman do accord the behavior of individuals the attention it deserves. In so doing they are able to specify more clearly what the sources of variation in the collective behavior of the firm are. Ultimately, the behaviors of individuals, and only these behaviors, are the sources of variation. While the resources of the firm can indeed provide a variety of productive services, it is the employees of the firm that decide how to deploy them. In the Penrosian view, this is rather simply determined by the perception of productive opportunities by the firm's management. In Burgelman's view, this is determined in a much more elaborate and subtle strategy process in which members of the organization take strategic initiatives that compete for managerial attention and resources in the internal selection environment of the firm.

What are the implications of these views for modeling the firm in terms of the Darwinian framework? It would seem that we need to combine three views of the firm, which all have equal currency in addressing important aspects of organizational learning as a source of productive knowledge. The first view is of the firm as a social entity. In this view, the firm is seen as a collection of individuals, whose behaviors underlie the way in which the firm interacts with its environment. From this point of view, we need to understand how individual behaviors are coordinated into the functional and recurrent collective action patterns that we call organizational capabilities. The second view is of the firm as an economic entity. In this view of the firm, the firm is seen as an entity that competes with other entities for scarce resources, and whose success in this competition (or lack thereof) determines its survival and growth. From this point of view, we need to understand how information from the market is fed back into the system so that competitive behaviors that work can be retained. What connects these two views of the firm is the concept of the codex. In the view of the firm as a social entity, the codex is a source of selection pressure. It is the internal selection environment to which individuals adapt their behavior. In the view of the firm as an economic entity, the codex is a source of functional behavior. It is where organizational knowledge resides. The third view of the firm is as a managed entity. In this view, the codex is a target for intervention that managers can try to manipulate in order to change the firm's capabilities.

Given these three views of the firm and the central, yet varied, roles of the codex in them, what do the theories discussed above suggest about the nature of the codex? What are the constituent elements of



firms, and what determines how these elements interact to produce behavior? The essential constituent elements are two types of resources: the individual members of the organization and the material and immaterial assets that it can access. Both types of resources can provide a variety of productive services. The productive services that the individual members of the organization can render depend on their behavioral repertoires. Underlying each member's repertoire of functional behaviors is individual knowledge. The administrative framework determines how the members of the organization and its assets interact. It serves two essential tasks: it determines both which productive services are called upon and how they are coordinated into collective action patterns. The first of these tasks is served by the firm's strategy, or the shared purpose of its members, the second by its internal organization, or the collection of coordinating mechanisms to which the individual members of the organization respond.

This results in a relatively straightforward definition of the codex of a firm. The codex of a firm is its specific combination of individual knowledge, assets, coordinating mechanisms, and shared purpose. These are what enable and constrain the behavior of the firm. They are both the source of internal selection pressures to which individuals adapt their behavior, and the source of the recurrent functional collective behaviors we call organizational capabilities. It is in these four elements of the codex that organizational knowledge resides. Organizations learn by either consciously or unconsciously changing one or more of these four building blocks, and feeding back the effects of these changes on the success of the firm in the market so that changes that work are retained.

## 5. CONCLUSION

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The aim of this paper has been to show how an evolutionary perspective can both ground and help to further develop knowledge-based and capabilities-based theories of the firm. If we want to do more than merely stipulate the existence of productive knowledge we need to consider this knowledge as the result of a learning process. Doing so can help us better understand the locus of productive knowledge and the building blocks of organizational capabilities. Darwinism offers a logically consistent explanatory framework that is uniquely suited to deal with the theoretical complexities of learning processes. A Darwinian view of organizational learning shows that there is a logical imperative to distinguish organizational knowledge from organizational capabilities, and generalized Darwinism offers a framework that shows how they are linked in a recursive causal structure that explains how organizations learn.

Darwinian logic leads to a view of the firm in which individual behavior is the only source of variation in organizational capabilities, but in which organizational knowledge also resides in collective properties of the firm such as assets, coordinating mechanisms and shared purpose. Together with individual knowledge, it is these organizational characteristics that are the building blocks of organizational capabilities. In the final analysis, organizational knowledge, capabilities, and learning can only be understood when we are willing to acknowledge that firms are both social and economic entities. As a social system firms coordinate the behavior of individuals. On this view organizational capabilities can be seen as recurrent collective action patterns. As an economic system firms compete with other firms on the basis of their capabilities. On this view organizational capabilities can be seen as the firm's repertoire of functional behaviors. Few theories are able to combine these two levels of analysis and bridge the micro-macro divide that bedevils much of the social sciences. It has recently been argued that evolutionary theory offers a perspective that can be instrumental in bridging this divide (Richerson and Boyd, 2005), and perhaps a Darwinian view of the firm can help fulfill this promise.

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